Influence of Gaps in Earth Radiation Budget Climate Data Records

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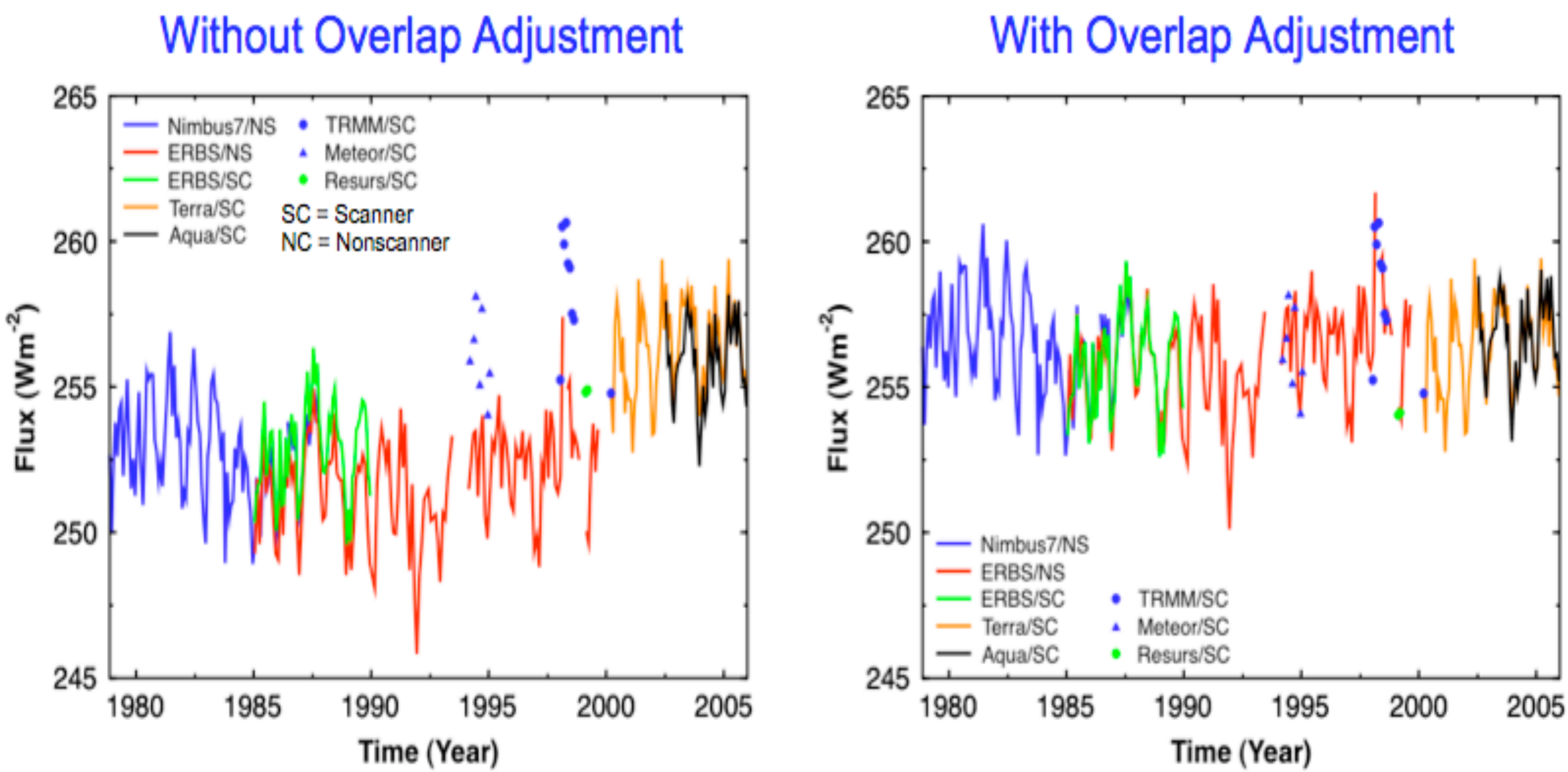
Introduction

- How does a gap in a climate data record affect our ability to constrain cloud feedback?
- How much overlap is needed between successive CERES instruments?

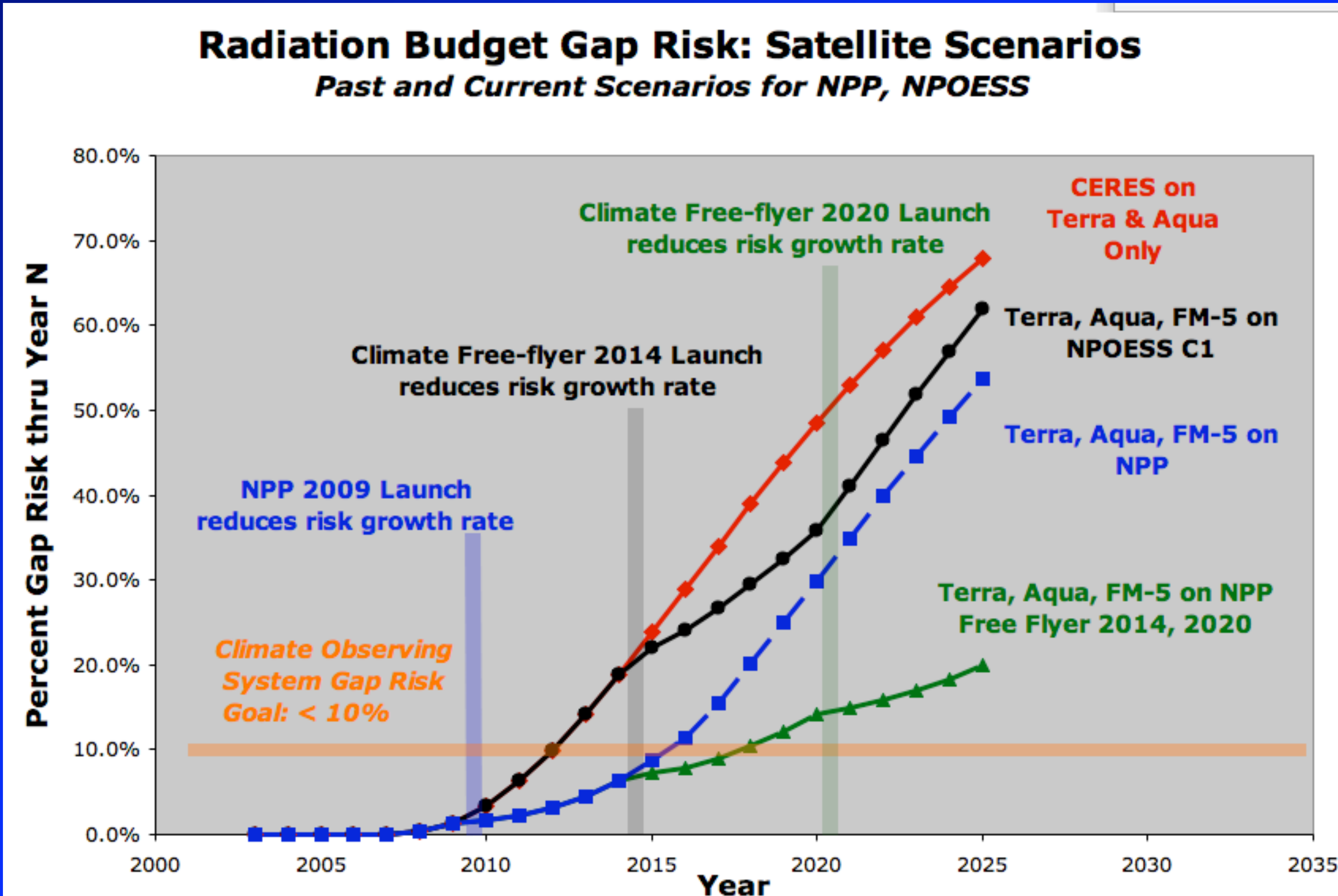
Tropical Mean (20°N to 20°S) Outgoing Longwave Radiation



- ***Instrument-to-instrument absolute calibration differences are 1 to 4 Wm^{-2}.***

=>Absolute accuracy alone is insufficient to detect climate change at the 0.6 Wm^{-2} per decade level of anthropogenic radiative forcing by greenhouse gases.

- ***Overlapping observations allows the use of instrument stability instead of absolute accuracy to constrain decadal climate change.***


Radiation Budget Gap Risk: Satellite Scenarios
Past and Current Scenarios for NPP, NPOESS
CERES on Terra & Aqua Only
Climate Free-flyer 2020 Launch reduces risk growth rate
Terra, Aqua, FM-5 on NPOESS C1
Climate Free-flyer 2014 Launch reduces risk growth rate
Terra, Aqua, FM-5 on NPP
NPP 2009 Launch reduces risk growth rate
Terra, Aqua, FM-5 on NPP Free Flyer 2014, 2020
Climate Observing System Gap Risk Goal: < 10%
Percent Gap Risk thru Year N
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
2000
2005
2010
2015
2020
2025
2030
2035
Year

CERES Climate Data Record Observational Requirements for Constraining Cloud Feedback

- The largest uncertainty in global climate sensitivity over the next century is cloud feedback (especially for low clouds).
- A global cloud feedback of 25% would amplify or dampen global warming by 25%.
- CERES can observe decadal changes in cloud radiative forcing that constrain the large uncertainty in cloud feedback and therefore climate sensitivity.
- Uncertainty in the CRE^{net} trend should be less **than 0.15 Wm^{-2} per decade** in order to constrain cloud radiative feedback to 25% of the anticipated change in anthropogenic radiative forcing over the next few decades (0.6 Wm^{-2}; Houghton et al. 2001).

Simulated 30-Yr Record in Net Cloud Radiative Effect
(Based on First 5 Yr of CERES-Terra Obs)

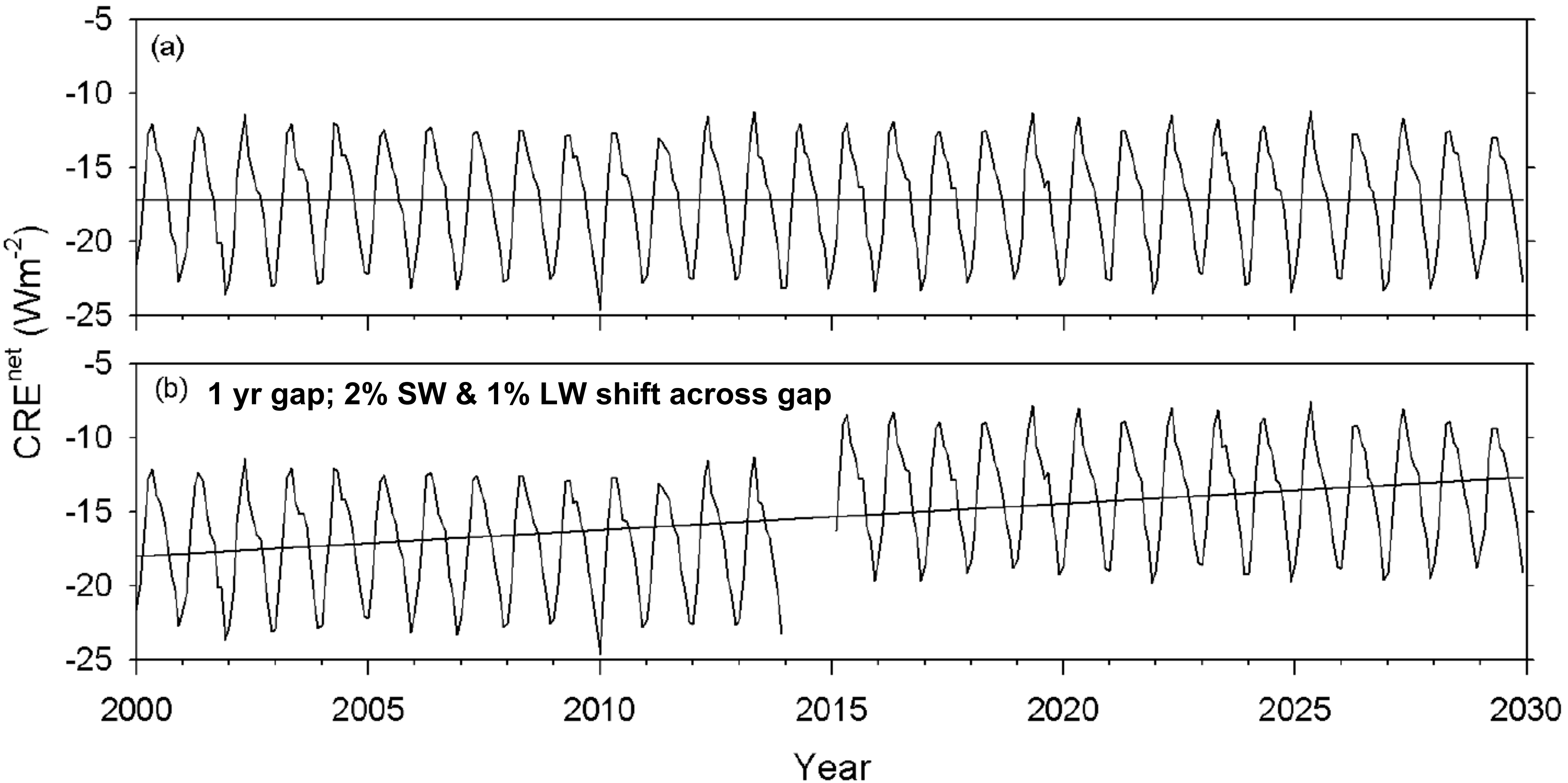


Figure 1 One realization of a 30-year time series in net cloud radiative effect for (a) no gap; (b) one-year gap starting in 2014 with an absolute calibration shift of -2% in the SW and -1% in the LW across the gap. Solid lines are least-square linear fits.

Uncertainty in net Cloud Radiative Effect due to Absolute Calibration Uncertainty

$$CRE^{sw} = F^{sw}_{clr} - F^{sw}_{all}$$

$$CRE^{lw} = F^{lw}_{clr} - F^{lw}_{all}$$

$$CRE^{net} = CRE^{sw} + CRE^{lw}$$

$$\delta CRE^{X} = \sqrt{(\delta F^{X}_{clr})^2 + (\delta F^{X}_{all})^2 - 2\rho^{X}\delta F^{X}_{clr}\delta F^{X}_{all}}$$

$$\delta F^{X}_{clr} = \Delta G F^{X}_{clr}, \quad \delta F^{X}_{all} = \Delta G F^{X}_{all}$$

$$\delta CRE^{net} = \sqrt{(\delta CRE^{sw})^2 + (\delta CRE^{lw})^2 + 2\rho^{net}\delta CRE^{sw}\delta CRE^{lw}}$$

Trend Error Due to a Gap in Record

$$E(\hat{\omega}) = \sqrt{(\hat{\omega} - \omega)^2 + (\delta\hat{\omega} - \delta\omega)^2}$$

ω Trend (no gap)

$\hat{\omega}$ Trend (with gap)

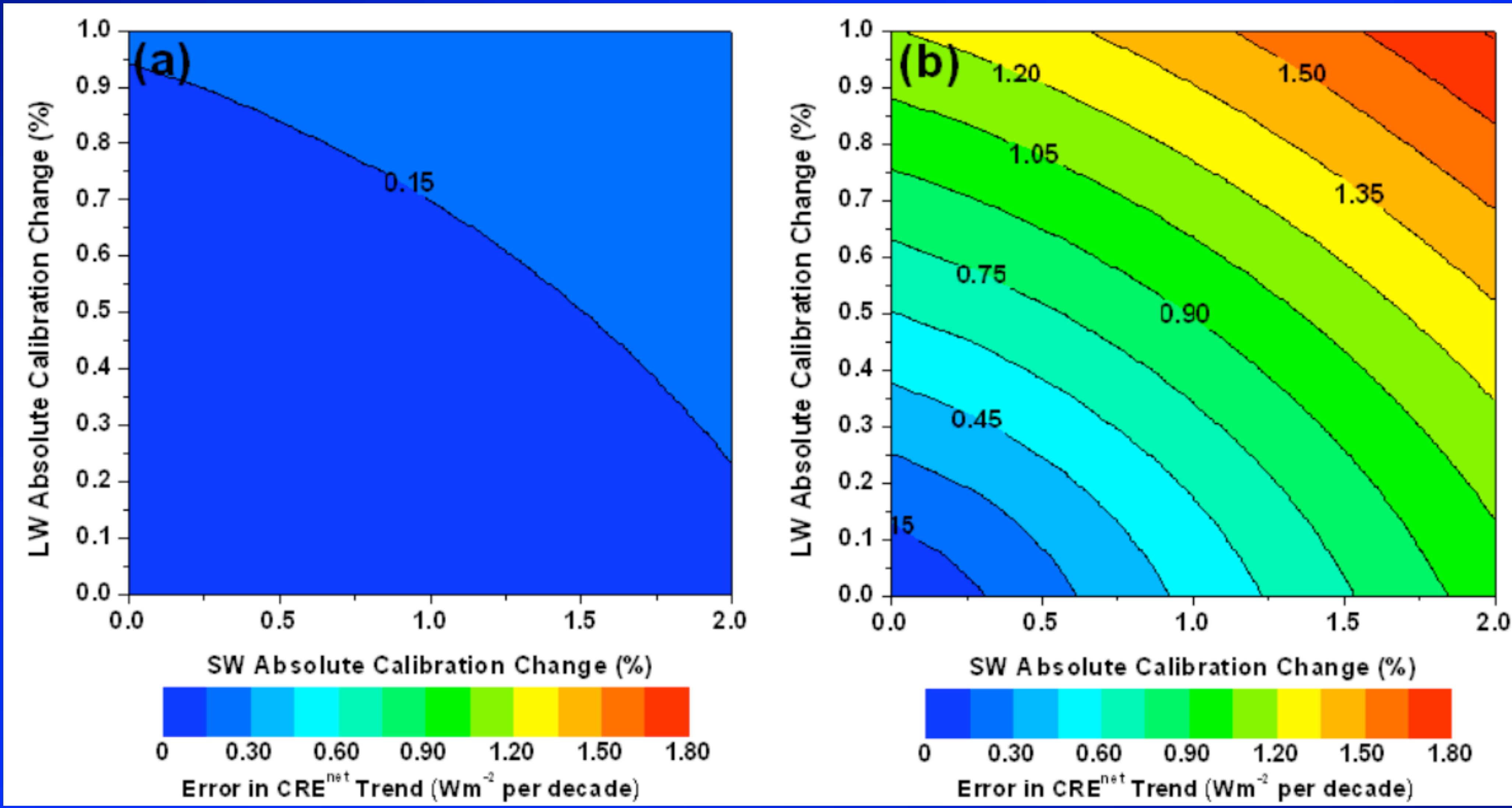
$\delta\omega$ 95% Confidence interval in trend (no gap)

$\delta\hat{\omega}$ 95% Confidence interval in trend (with gap)

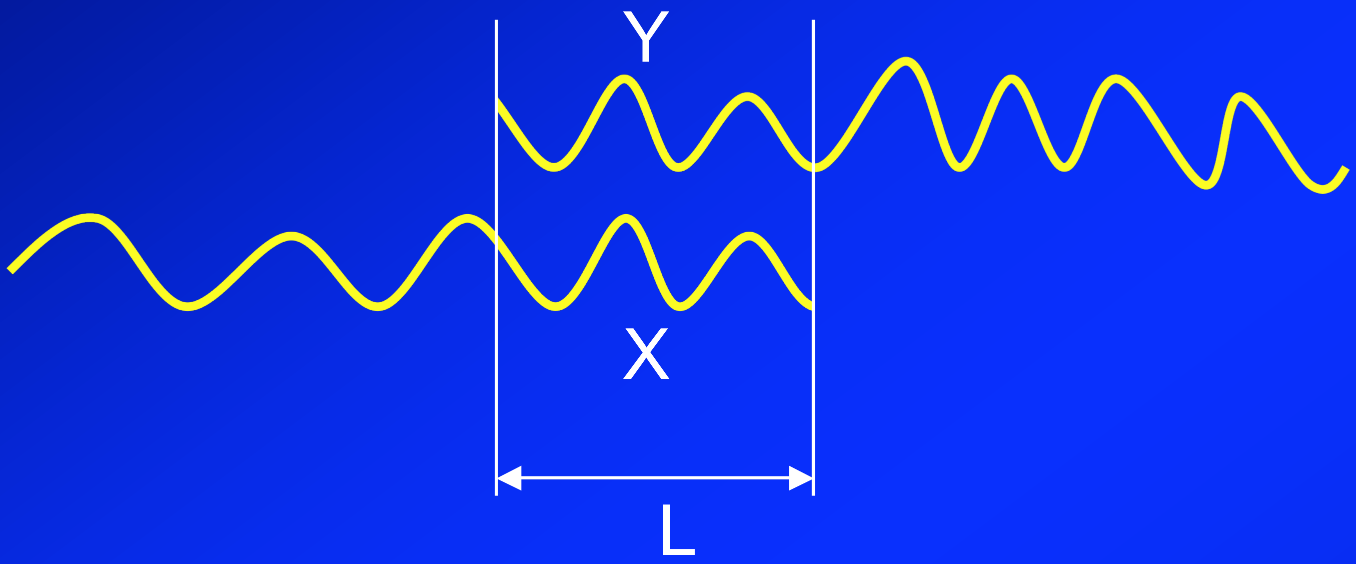
Error (2σ) in Net Cloud Radiative Effect Trend Due to 1-Yr Gap as a Function of SW and LW Absolute Calibration

Gap at Beginning of Record

Gap in Middle of Record



How Much Overlap Time is Necessary Between Successive Instruments?



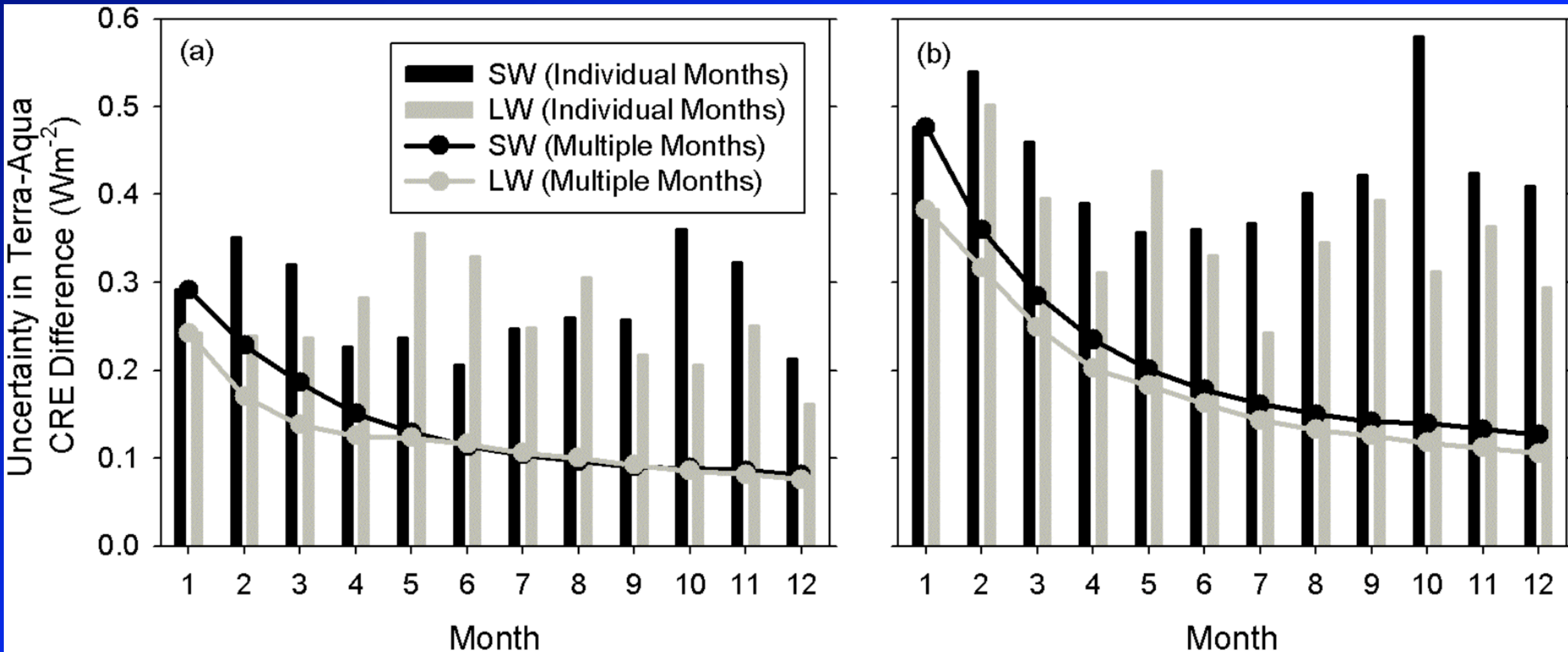
$$Z = | \langle X \rangle - \langle Y \rangle |$$

$$\delta Z_j = \sqrt{\delta X_j^2 + \delta Y_j^2 - 2\rho_{X_j Y_j} \delta X_j \delta Y_j}$$

Determine L such that $\delta Z < 0.15\ Wm^{-2}\ decade^{-1}$

- Use one year of overlap between CERES Terra & Aqua to determine L.

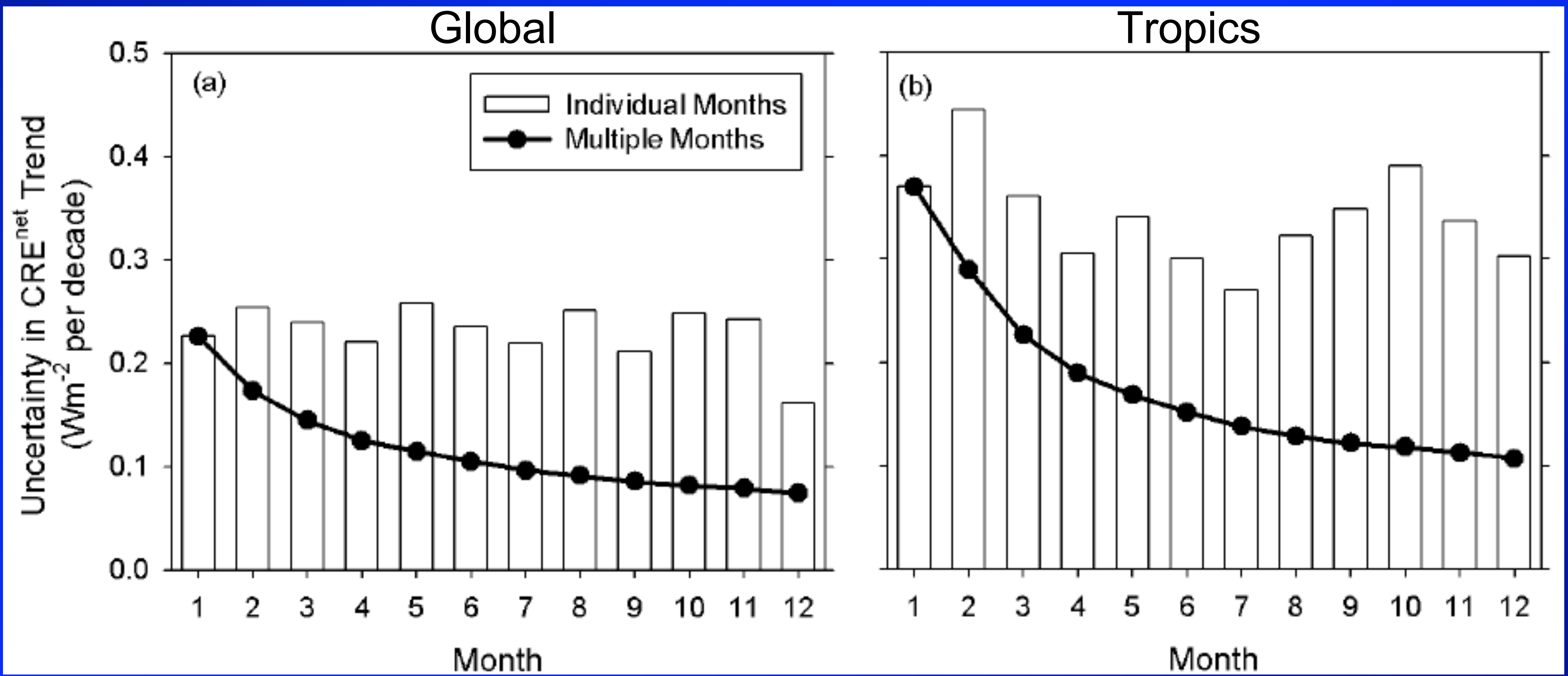
Uncertainty in Terra–Aqua Monthly Mean Difference in CRE



- Determine monthly mean CRE from daily means for CERES Terra and Aqua.
- For each month compute δCRE(Terra), δCRE(Aqua) and ρ.
- Above plot shows uncertainty in the Terra-Aqua CRE difference for each month and when several months are combined.

Overlap Requirements

- Determine number of overlapping months required to reduce random uncertainty in the difference between the two overlapping data records to ensure a 30-year trend uncertainty of < 0.15 Wm^{-2} per decade.
- Use overlap between Terra and Aqua in 2004 to determine random error.



Multiple overlapping months: the trend uncertainty reaches 0.15 Wm^{-2} per decade after ~3 months for the globe, and 6 months for the tropics.

Conclusions

- Current ERB instruments are far more precise than they are absolutely accurate.
- A gap in the middle of the data record has far greater impact than a gap near the beginning.
- To constrain cloud radiative feedback to 25% of anthropo-genic forcing in next few decades, the absolute calibration change across the gap must be < 0.3% in the SW and 0.1% in the LW.

  => This is well beyond the capability of current ERB instruments. A gap of any length restarts the record at zero.
- To overcome the effect of a gap, observing systems require six months of overlap between successive instruments in order to tie the data record of one instrument to the next.

=> More details in Loeb et al., JGR, 2008 (submitted)

CERES Flight Schedule

Enabling Climate Data Record Continuity

Spacecraft	Instruments	Launch	Science Initiation	Collected Data (Months)
TRMM	PFM	11/97	1/98	9
Terra	FM1, FM2	12/99	3/00	98 +
Aqua	FM3, FM4	5/02	6/02	71 +
NPP	FM5	June 2010	-	-
NPOESS C1	*FM6*	*January 2013*	-	-
NPOESS C3	*CERES follow-on*	*January 2018*	-	-

31 Instrument Years of Data